under such uniform conditions would be exceedingly valuable, not only in giving the highest order of results in timekeeping, but also in developing the peculiarities and comparative merits of the clocks themselves. The extreme accuracy with which two clocks, one keeping sidereal and the other mean time, can be compared by coincidences of the beats, which take place every six minutes, is familiar to every astronomer. Again, the more rapid minor variations in the rates of clocks could perhaps be detected and their periodicity determined by comparison with the vibrations of a pendulum swinging in vacuo.

Improvement in performance of astronomical clocks is of special importance in fundamental astronomy. An independent redetermination of the positions of the fundamental stars is necessary, and for this the most accurate possible timekeeping is needed because, in order to be of value in the present state of astronomy, such work must be of the highest degree of accuracy. All this has long been recognized by astronomers, and during the past forty years efforts in the direction of improved timekeeping have been made in all the principal observatories of Europe where fundamental work is attempted.

Commenting on the bad effect of variations in the rates of astronomical clocks due to the diurnal changes of temperature, Professor Foerster, the distinguished astronomer, who has been for 38 years director of the Royal Observatory at Berlin, wrote in 1867:

"How detrimental to accuracy such a large and changeable irregularity is, is evident since it operates like a variable division error.

"It is therefore necessary, in order that a clock may be of service in absolute determinations of star places, to have it protected from the daily temperature change, and also from all sudden changes of temperature. That is, it should be mounted in a place of nearly constant daily temperature so that it will remain for the compensation of the pendulum to effect only the last remaining fine adjustment.

"The air-tight confinement is safe in underground rooms or in heavy masonry against injury to the clock-work, because in the hermetically enclosed space any moisture present can be done away with by known means and the coming in of new moisture is impossible."

Milton Updegraff.
U. S. Naval Observatory,
Washington, D. C.

SCIENTIFIC BOOKS.

The Stars, A Study of the Universe. By Simon Newcomb. Pp. v+333. New York, G. P. Putnam's Sons; London, John Murray.

This is professedly a book written to order, as a part of the science series now appearing under the editorial supervision of Professor Cattell, and its author states plainly in his preface that he has found the task, 'to sketch in simple language for the lay as well as the scientific reader the wonderful advances of our generation in the knowledge of the fixed stars,' much more onerous than he had anticipated, on account of 'the extent and complexity of the subject and the impossibility of entering far into technical details in a work designed mainly for the general use.'

If one may judge the extent of systematized knowledge concerning the fixed stars by the space allotted to its presentation in the most approved text-books of general astronomy, from that of Arago to the present time, it appears that this branch of astronomy has grown during the century from about one eighth to one sixth part of the entire science. But the indexes to recent volumes of the principal astronomical periodicals show that about one-third of the articles there appearing relate to problems of stellar astronomy and thus mark an accelerated growth of interest in and knowledge of the remoter parts of the visible universe. The author who attempts to digest

this rapidly accumulating material and to present its substance in untechnical form merits the thanks of both professional and lay readers, even though occasional inaccuracies or omissions affect the text or the rapid advance of knowledge renders obsolete some passages before the ink is dry upon the pages. A double acknowledgment is due when, as in the present case, that author is the one astronomer marked out by long and distinguished service in important parts of this field as peculiarly adapted to the task. The title, Retired Professor U. S. Navy, that follows the author's name upon the title page, suggests thoughts far from complimentary to that fatuous governmental policy in accordance with which astronomers are retired from the public service upon reaching an age limit not far removed from the maximum of intellectual power.

In substance, though not in formal arrangement, the present work falls naturally into two parts; first, a description of methods of research and such elementary classification of stars as are the familiar province of the better text-books, *e. g.*, the grouping of stars into constellations, the explanation of stellar magnitudes, proper motions, parallaxes, stellar spectroscopy, the description of the phenomena presented by variable and double stars, nebulæ, etc.; and second, a more original part devoted to the larger problems of stellar distribution, the significance of the milky way, the sun's motion, stellar evolution and similar matters which may be grouped, fairly enough, under the title, the structure of the heavens. We welcome here a presentation of some of Kapteyn's results not hitherto accessible, of Huggins's views of stellar evolution, and the author's own methods, inferences and conclusions from the new material collected and sifted in the preparation of this work. As types of these last-named categories it is interesting to note the simple statistical method (p. 300) by which certain results first obtained by Kapteyn through an elaborate and tedious mathematical process are independently derived. Of a very different order is the suggestion made with reference to Bailey's discovery of variable stars in clusters, that there is 'a strong presumption that the variations in the light of these stars are in some way connected with the revolution of bodies round them, or of one star round another.' The distribution of the stars in space is treated with a fullness of detail that occasions some surprise at the almost complete neglect of a possible absorption of starlight in the interstellar spaces; a possible defect of transparency in the celestial void, that has been rendered a classic theme by Struve's speculations and more recently has been elaborated by Schiaparelli.

Taken as a whole the work contains in excellent form a large amount of material interesting to the professional astronomer and in even larger measure valuable to the popular expositor of astronomy, teacher, lecturer or writer. As it is sure to be largely drawn upon by this class it seems important to eliminate as rapidly as possible those errors and inaccuracies inseparable from a first edition, among which we note the following:

P. 158, line 10, for eleven read five and one-half.

P. 182, line 3, for Triphid read Trifid.

P. 194, insert a^3 in the numerator of the fraction.

P. 198, line 1, for $2m$ read 2^m.

The statement made on p. 179 with regard to the Orion nebula, 'This is plainly visible to the naked eye and can be seen without difficulty whenever the constellation is visible,' does not at all correspond to the experience of the present writer who has great difficulty in seeing the nebula with unaided vision, even under favorable circumstances, and whose experience is shared by a dozen young people, of both sexes, who at his request have looked for the nebula.

In the matter of nomenclature some objection may fairly be raised to the apparently needless introduction of new terms in place of the familiar old ones, such as the logically inappropriate, apocenter, pericenter, for apastron, periastron, in connection with double star orbits, and the rechristening of the Fraunhofer lines of the solar spectrum as Wollaston lines. But with all due allowance for such minor blemishes the book remains in its entirety a notable contribution to the literature

of astronomy. Its style is clear and attractive and the illustrations, some excellent, are in the main adequate although many of the diagrams are disagreeably crude. A familiar literary device, that of prefixing a brief metrical introduction to each chapter, has here been so felicitously applied as to deserve especial mention. An excellent table of contents and index greatly facilitate the use of the work as a book of reference. George C. Comstock.

EARTH-CURRENT OBSERVATIONS IN THE GERMAN TELEGRAPH SYSTEM.*

The origin of these important observations dates back to 1881, when a committee was called together by Werner Siemens, to study the phenomena of earth-currents. Through their efforts, two underground cables were provided by the Imperial Telegraph System, one running in an easterly direction from Berlin to Thorn, 262 km., the other nearly due south from Berlin to Dresden, 120 km. The present work deals chiefly with the continuous observations of earth-currents from these two lines, from 1884 to 1888. The Prussian Academy of Sciences assisted, in part, in the maintenance of the observations.

The assumption is made at the start that the observed currents are due to potential differences between the ends of the lines; that is, they are derived from currents that flow in closed circuits within the earth, parallel to its surface. Of course *vertical* differences of potential have to be left out of consideration.

The attempt to express the intensities in the two lines by trigonometrical formulæ according to Gauss, using the latitude and longitude as variables, leads to equations whose constants are too difficult to be determined. Assuming the validity of Ohm's law, however, the intensity of the earth-current components in the two directions may be given by the equations

$$J = A\frac{W}{L}i, \quad J' = A\frac{W'}{L'}i',$$

where A is a constant and W, W' are the resistances, L, L' the lengths and i, i' the observed current strengths in the two lines respectively.

We thus obtain for the total earth-current,

$$E = A\sqrt{\frac{W^2}{L^2}i^2 + \frac{W'^2}{L'^2}i'^2}.$$

The value of the constants was computed for each of the two lines. The results are only relative, however, as no reductions to absolute units were made.

The most characteristic feature of earth-current variations is their dependence upon the position and condition of the Sun. The diurnal and annual variations are especially marked. In view of this, the attempt is made to modify the trigonometrical representation in such a way as to use, instead of the latitude, the angle with the Sun's declination, and for the longitude, the local time or the right ascension of the Sun. The results indicate, however, as was to be expected, that this is not sufficient, but that other factors have to be considered. In general there can be distinguished a constant component of the current, due to terrestrial and local conditions, and a variable component, depending chiefly upon the Sun. The four years of observations were not enough to make the derivation of accurate formulæ possible. As approximations, however, expressions for the components in the two directions were derived, as functions of the local time and its multiples, from which the diurnal variation is made evident.

The self-recording instruments were of two different types. In the Berlin-Dresden line a Siemens 'Russschreiber' was used, in the other line a mirror-galvanometer reflected a beam of light on to photographic paper. The sensitiveness of both instruments was frequently determined, and though the results were not reduced to absolute measure, still it is always possible to get accurate relative values between the two lines.

The magnetic records, which, as the title indicates, formed an essential part of the work, were obtained chiefly from the observatories at Wilhelmshaven and Vienna, but to a lesser extent also from the observations during the

* Die Erdströme im deutschen Reichstelegraphengebiet und ihr Zusammenhang mit den erdmagnetischen Erscheinungen, bearbeitet und herausgegeben von Dr. B. Weinstein. Braunschweig, Friedrich Vieweg & Sohn, 1900.